OLED Manufacturing R&D

Priorities from April OLED Roundtable Meeting

David A Newman
Executive Vice President
Moser Baer Technologies, Inc.

DOE OLED SSL Roadmap

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From July 2011 DOE SSL Manufacturing Roadmap:

FACTOR	UNITS	2012	2015	2020
Substrate Area	m^2	0.17	0.67	1.95
Substrate utilization	%	70	80	80
Yield of good panels	%	75	90	95
Equipment uptime	%	50	75	90
Cycle time	sec	120	30	20
Annual production	1000 m^2	12	380	2100
Equipment cost	$M	60	150	250
Depreciation	$/$m^2$	1000	80	24

Materials	$/$m^2$	180	91	42
Depreciation	$/$m^2$	1000	80	24
Labor	$/$m^2$	400	40	10
Operations	$/$m^2$	120	24	8
Overhead	$/$m^2$	100	15	6
Total	$/$m^2$	1800	250	90
Total	$/k lumen	180	25	9

2012 Reality Check

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FACTOR	UNITS	2012	2015	2020
Materials	$/m^2	180	91	42
Depreciation	$/m^2	1000	80	24
Labor	$/m^2	400	40	10
Operations	$/m^2	120	24	8
Overhead	$/m^2	100	15	6
Total	$/m^2	1800	250	90
Total	$/k lumen	180	25	9

Materials cost alone is currently > $2000/m^2

Cost Reduction - Materials

- Lower cost integrated substrate technology
- Lower cost encapsulation technology
- Organic materials $$$, better utilization

Target: < $52/m^2 by 2015

< $20/m^2 by 2015

< $10/m^2 by 2015

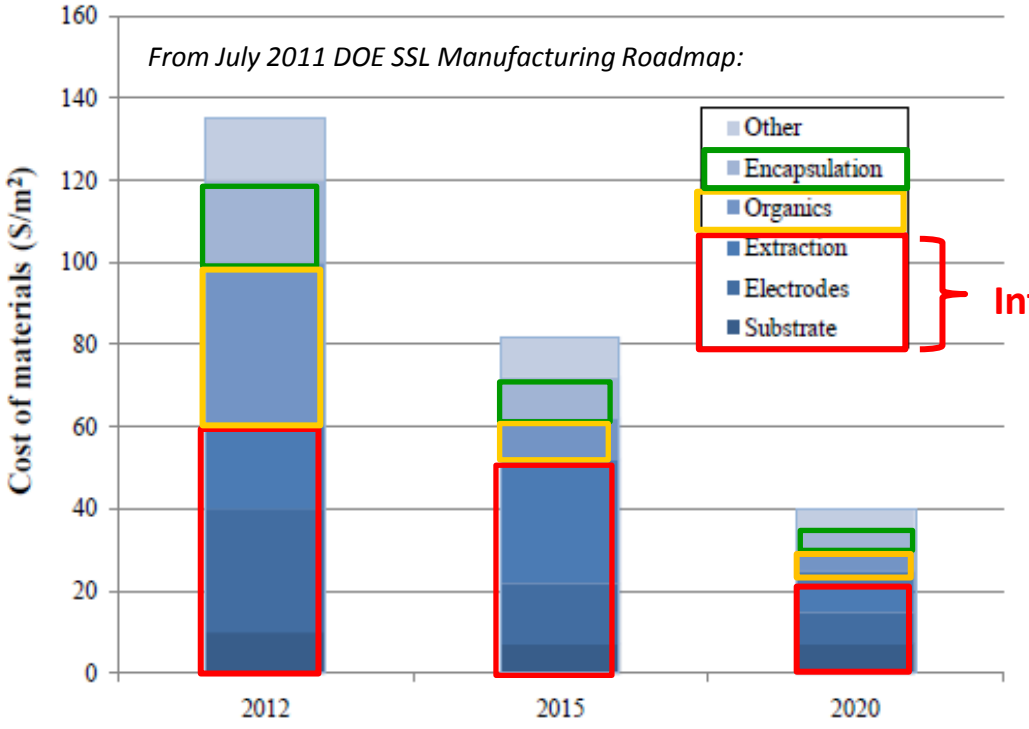

Figure 11. Cost of materials as deposited on processed substrates ($/m^2)
Source: Based on data provided by the 2011 Manufacturing Roundtable Attendees

Substrate Costs

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Current Status:

Glass + TCO + Metal + Planarization (all patterned by photolithography/etch)

+ External light extraction film

Currently > $1000/m^2

Low cost integrated substrate technology needed:

- Glass (soda lime): $5/m^2
- Patterned TCO: $15/m^2
- Grid Materials: $15/m^2
- Integrated Light Extraction: $15/m^2
- Low cost patterning techniques (printing, laser, etc.)

Target: < $52/m^2 by 2015

Encapsulation Costs

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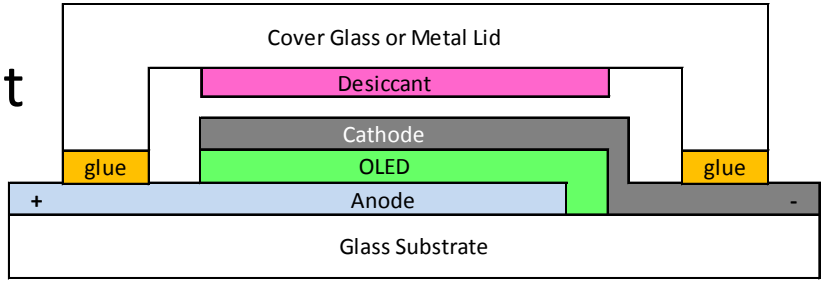
Current Status:

- Cavity Glass + Edge seal + Desiccant

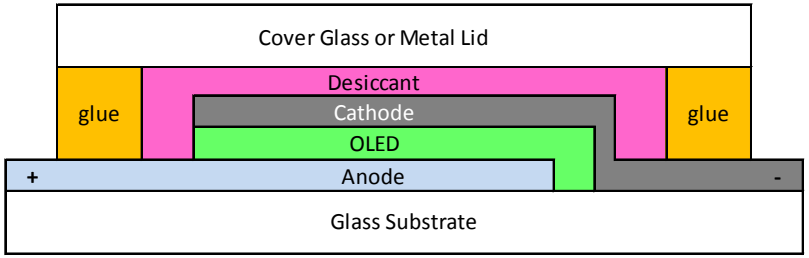
Currently > $500/m²

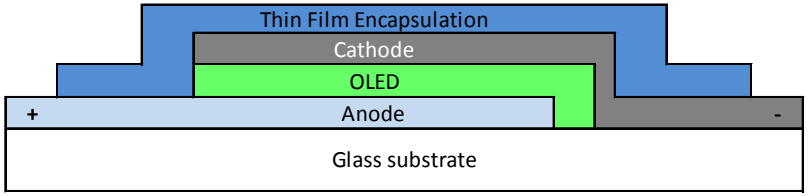


Low cost encapsulation technology needed:

- Flat glass or metal + edge seal + desiccant
- Frit glass (laser seal)
- Thin film encapsulation

Target: < $20/m² by 2015





Organics Cost

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Current Status:

- Point sources or area sources, poor utilization < 10%
- Linear sources, 10-20% utilization
- Lower volumes = higher cost for organic materials

Currently > $500/m^2

Lower cost organic materials and better source technology needed:

- Linear or area sources with > 50% utilization
- Higher volumes = lower costs, volume discounts (increased demand from OLED lighting and display makers)

Target: <$10/m^2 by 2015

Roadmap

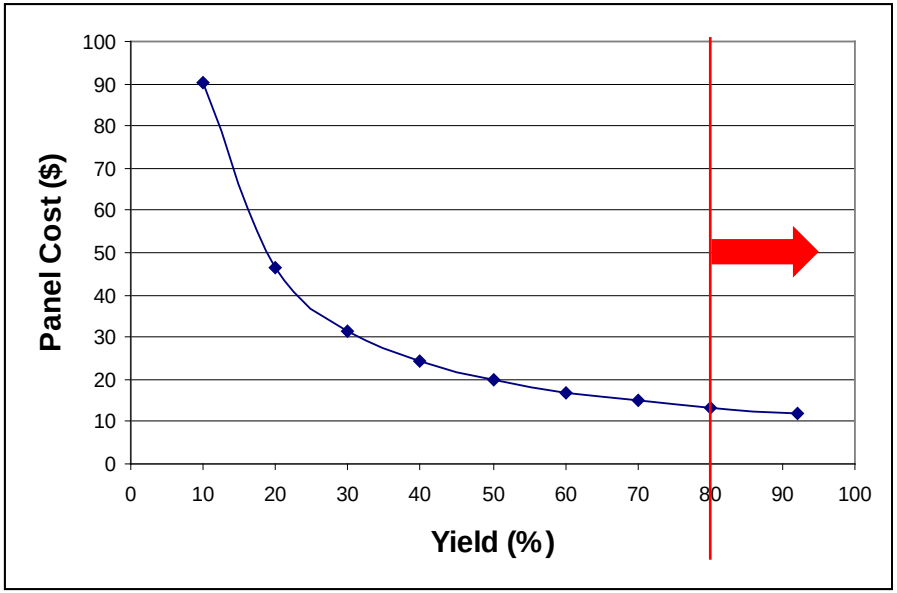
July 2011 SSL Manufacturing Roadmap Page 66

M.O3. OLED Materials Manufacturing: Support for the development of advanced manufacturing of low cost integrated substrates and encapsulation materials. Performers or partners should demonstrate a state of the art OLED lighting device using the materials contemplated under this task.		
Metric(s)		**2015 Target(s)**
Substrate	Total cost – dressed substrate	$\$52/m^2$
	Transmission	>85%
	Surface Roughness	Rrms < 2nm; Rpv < 20nm
	Sheet Resistance	<10 ohms/square
Encapsulation	Permeability of H_2O	10^{-6} $g/m^2/day$
	Permeability of O_2	$10^{-4} cc/m^2/day/atm$
	Cost	$\$10/m^2$

Cost Reduction - Yield

Reduce cost of OLED lighting through yield improvement:

- Improve manufacturing tolerances in both production equipment and processes
- Implement robust quality control methods and tools to reduce non-yielded products and minimize the need for binning



Assumed yields from July 2011 DOE SSL Manufacturing Roadmap:

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Achieve >80% yield by 2014
Achieve >90% yield by 2015

DE-EE0005065 MBT/UDC – "Improving Product Yield of OLEDs"

Yield

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Process Yield x Product Yield = Overall Yield

Process Yield

Target > 90%

- Broken/cracked panels
- Added defects – fails inspection
- Out-of-control, fails process specifications:
  - Glass cleanliness
  - ILE/ELE quality, uniformity
  - TCO thickness, Rs, uniformity
  - Metal thickness, linewidth
  - Planarization quality
  - OLED deposition quality (thickness, composition, uniformity)
  - Encapsulation quality

Product Yield

Target > 90%

- Shorted panels
- Visual defects, darkspots, muras
- Back-end module assembly, electrical connection quality
- Out-of-spec performance – fails product specifications:
  - Color quality (CCT, duv, CRI)
  - Color/brightness uniformity
  - Efficacy
  - Lifetime (lumen/color maintenance)

Yield depends on product specifications!

Overall Yield Target > 80%

(0.9 x 0.9 = 0.81)

Summary

We think yield targets can be achieved. Moser Baer Technologies and Universal Display Corporation are working on this with funding assistance from project DE-EE0005065 MBT/UDC – "Improving Product Yield of OLEDs"

But: cost targets can't be met until progress is made on integrated substrate and encapsulation materials and processes, and until high volumes are achieved